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# Price Elasticity of Export Demand

## Concepts and Estimates

Walter H. Gardiner  
Praveen M. Dixit



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#### ABSTRACT

Price elasticity of export demand is an important parameter that determines the effect of price changes on export earnings. This report analyzes the price elasticity of export demand in general and reviews recent estimates for selected U.S. agricultural commodities. While there is little consensus on the size of this parameter, these studies suggest that the shortrun (1 year or less) price elasticity of export demand for U.S. grains, soybeans, and cotton is inelastic. The longrun (more than 1 year) evidence is even less conclusive. Few studies estimate the longrun price elasticity of demand for U.S. agricultural products; and their estimates range from very inelastic to very elastic.

Keywords: Price elasticity, export demand, estimation methods, wheat, coarse grains, soybeans, rice, cotton.

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## SUMMARY

This report defines price elasticity of export demand and discusses factors that affect its value. The report also examines how the adjustment period, government policies, domestic structure of trading countries, and export market shares affect the elasticity of export demand. Recent estimates of the elasticity of export demand for selected agricultural commodities are also presented.

There is little consensus on estimates of the price elasticity of export demand for U.S. wheat, coarse grains, soybeans, rice, and cotton. The parameter for each of the commodities varies widely from very inelastic (less than 1 in absolute value) to very elastic (greater than 1 in absolute value) in both the short run (less than 1 year) and the long run (more than 1 year). The wide variation in elasticity estimates reported in the literature is attributed primarily to differences in methods, assumptions, and analysis periods.

Although definitive estimates for export demand elasticities are not available, many studies indicate that the shortrun export demand for U.S. grains, soybeans, and cotton is price inelastic. The longrun evidence is even less conclusive. There are substantially fewer studies that estimate the longrun price elasticity of demand for U.S. agricultural products, and the estimates vary widely.





# Price Elasticity of Export Demand

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### INTRODUCTION

Price elasticity of export demand for U.S. agricultural products specifies a relationship between an export price and the quantity exported of a specific commodity. It summarizes in one parameter the reactions of both importing and exporting countries to a price change by the United States. The reactions of these countries, in turn, depend upon their trade and domestic policies and the extent that U.S. prices influence their production, consumption, and stockholding decisions.

Whether the demand for U.S. exports is price elastic or inelastic is important, especially for marketing strategies and government policy decisions. One needs to know the price elasticity of export demand to answer questions like: How much will the demand for exports of a commodity vary when a price changes? If the United States lowered nonrecourse loan rates for grains and other commodities, thereby permitting export prices to decline, how much will exports increase and will export revenues expand or decline? How much will price vary in response to a change in the amount of a commodity a country offers for export?

We know that the elasticity of demand for U.S. exports changes over time, partly because of the overall change in world trade volume and the change in U.S. share of trade. In addition, structural changes in trade and domestic policies of other countries may change a country's reaction to world price.

This report evaluates estimates of the price elasticity of export demand for U.S. agricultural products. Elasticity of export demand is defined and some of its most important characteristics are reviewed. Alternative methods for estimating the elasticity of export demand and factors that determine its value are discussed. Recent estimates of this parameter for selected U.S. agricultural commodities are reviewed and the state of the art for estimating export demand elasticities is assessed.

## WHAT IS THE PRICE ELASTICITY OF EXPORT DEMAND?

The price elasticity of export demand is the responsiveness of export demand for a commodity to a change in its price, other things unchanged. Economists measure the degree of price responsiveness by the elasticity coefficient:

$$\text{Exd} = \frac{\text{Percentage change in the quantity of exports demanded}}{\text{Percentage change in price}} \quad (1)$$

Export demand for a commodity is:

1. "Elastic" if a given percentage change in price results in a greater percentage change in quantity;
2. "Inelastic" if a given percentage change in price results in a smaller percentage change in quantity; or
3. "Unitary elastic" if a given percentage change in price results in the same percentage change in quantity.

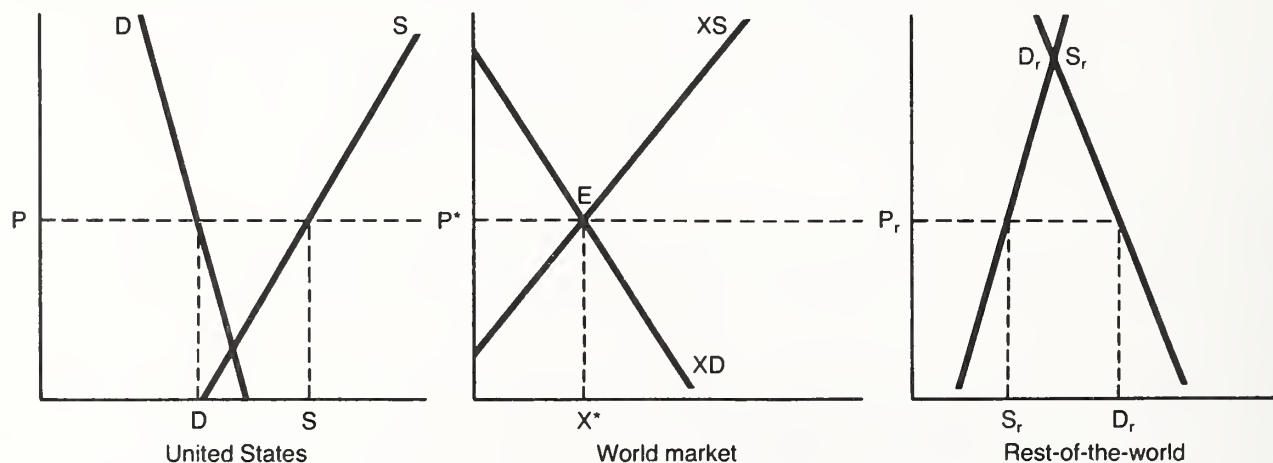
A single-commodity, two-region trade model is used to analyze this concept. Figure 1 illustrates the domestic markets of two countries and the international trade sector for a single commodity. Conventional economic logic is assumed here--as the price of a commodity rises, all other things constant, producers in all countries supply more and consumers demand less. The curves represent producer and consumer price behavior only for a particular time, such that they are "iso-temporal" (Baumol, 1977).

Figure 1

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### Single-commodity, two-country world trade model: free trade

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These curves will change with changes in other factors that influence supply (weather, technology, policy, and other prices) and demand (income, population, foreign exchange, policy, and other prices).

For simplicity, the world is assumed to consist of one exporting country, the United States, and one importer, the rest of the world (ROW). The domestic supply and demand curves for the United States are labeled  $S$  and  $D$ , respectively. The domestic supply and demand curves for the ROW are labeled  $S_r$  and  $D_r$ , respectively. The middle diagram represents the world market for a particular commodity. The excess (export) supply curve of the United States, labeled  $XS$ , represents the amount available for export. Export supply is determined by varying the price  $P$  in the United States and taking the difference between supply  $S$  and demand  $D$  at each price.

The excess (export) demand curve for the ROW, labeled  $XD$ , represents the amount domestic demand  $D_r$  exceeds domestic supply  $S_r$  at each price level  $P_r$  in the ROW. The  $XD$  curve represents the horizontal summation of the domestic supply and demand curves of all countries outside the United States trading in the commodity on the world market. Before horizontal summation, the price arguments for all supply and demand curves must be converted to a common currency, for example, the U.S. dollar. The excess demand curve must also be adjusted for quotas, tariffs, subsidies, transport costs, domestic policy distortions, and other market frictions (Thompson, 1981).

Assuming fixed exchange rates and no transportation costs, the intersection of the excess supply curve of the United States  $XS$  and the excess demand curve of the ROW  $XD$  occurs at point  $E$ , with equilibrium price at  $P^*$  (i.e.,  $P_u = P_r = P^*$ ) and exports at  $X^*$  (i.e.,  $XD = XS = X^*$ ).

The price elasticity of export demand measures how exports respond to price at points on the excess demand curve  $XD$ . For a downward-sloping excess demand curve, the price elasticity will be negative since price and quantity are negatively related. The absolute value of the elasticity coefficient,  $|Exd|$ , is typically used in determining how export demand responds to a price change:

1. If  $|Exd|$  is greater than 1, export demand is price elastic;
2. If  $|Exd|$  is less than 1, export demand is price inelastic; and
3. If  $|Exd|$  is equal to 1, export demand is unitary elastic.

The value of  $|Exd|$  theoretically can range from a low of zero to a high of infinity.  $|Exd|$  equals zero when a change in price results in no change in export demand--termed "perfectly inelastic demand." This is illustrated by an excess demand curve that is perpendicular to the quantity axis.  $|Exd|$  equals infinity when a small decrease in price causes buyers to increase their purchases from zero to all they can acquire--termed "perfectly elastic." In this case, the excess demand curve is parallel to the quantity axis. In reality, the excess demand facing the United States for its commodities will generally be downward sloping and the value of  $Exd$  will lie somewhere between the two extremes. The important issue is whether the export demand for a particular commodity is price elastic or inelastic.

The degree of price elasticity has an important relationship to the level of export revenue:

1. If export demand is price elastic, then an increase (decrease) in price will decrease (increase) export revenue;
2. If export demand is price inelastic, then an increase (decrease) in price will increase (decrease) export revenue; and
3. If export demand is unitary elastic, an increase or decrease in price leaves export revenue unchanged.

#### ESTIMATING THE PRICE ELASTICITY OF EXPORT DEMAND

Economists use a number of empirical methods to estimate the elasticity of export demand. These include direct estimation, calculation, simulation, and the synthetic method.

##### Direct Estimation Method

One method widely used in obtaining empirical estimates of the price elasticity of export demand is the direct estimation method. It entails econometrically estimating a reduced-form excess demand function facing the exporting nation.

Because the excess demand curve represents the net effect of all supply and demand adjustments in all other trading countries, all shifters of domestic supply and demand schedules in all trading countries should be variables in a correctly specified demand equation for U.S. exports. The general specification of an export demand equation might be:

$$XD_t = f(P_t, Z_t) \quad (2)$$

where  $XD_t$  is the demand for U.S. exports of some commodity at time period  $t$ ,  $P_t$  represents the price of the commodity, and  $Z_t$  represents other explanatory variables representing shifters of supply and demand schedules of trading countries (prices, income, government policies, weather, transportation costs, exchange rates, credit, and foreign exchange reserves). Only a small subset of all possible explanatory variables is actually used in estimating export demand relationships because of various methodological problems (degrees of freedom, multicollinearity, and missing data). This generally leads to biased parameter estimates (Kmenta, 1971, pp. 393-95).

A typical export demand function in linear form might be:

$$XD_{it} = \beta_0 + \beta_1 P_{it} + \beta_2 P_{jt} + \beta_3 Y_t + U_t \quad (3)$$

which relates the export demand for some commodity  $i$  at some time period  $t$  ( $XD_{it}$ ) to its price  $P_{it}$ , the price of other commodities  $P_{jt}$ , the income of importing countries  $Y_t$ , and a stochastic disturbance term  $U_t$ . The elasticity of export demand for a continuous function is in mathematical terms:



$$\text{Exd} = \frac{\partial \text{XD}_t}{\partial P_t} \cdot \frac{P_t}{\text{XD}_t} \quad (4)$$

Once equation (3) has been estimated, the price elasticity of export demand is obtained by applying formula (4), yielding:

$$\text{Exd} = \beta_1 \cdot \frac{P_t}{\text{XD}_t} \quad (5)$$

Thus, the price elasticity of export demand at a particular point is simply the product of the estimated price coefficient  $\beta_1$  and the ratio of price  $P_t$  to the corresponding level of exports  $\text{XD}_t$ . Elasticities are often calculated at their mean values, indicating the average price responsiveness of exports over some period. In this case,  $P_t$  and  $\text{XD}_t$  would be replaced by their mean values in the elasticity formula.

For the excess demand curve depicted in figure 1, the estimated price coefficient  $\beta_1$  corresponds with the estimated slope of that curve. The price elasticity of export demand  $\text{Exd}$  at point E is the product of the estimated slope of the excess demand curve and the ratio of the price  $P^*$  and exports  $X^*$ .

Since  $\text{Exd}$  is defined only for a particular point on the excess demand curve, then the impact of a price change holds only for a small movement around that point. Its value will vary for a movement along the excess demand curve as well as for a shift or a change in the shape of the curve. Moving up along a linear excess demand curve increases  $\text{Exd}$  because  $P$  increases,  $X$  decreases, and the slope remains unchanged. Moving down the curve causes  $\text{Exd}$  to drop because  $P$  decreases while  $X$  increases. Here, demand for exports is more price responsive at high prices than at low prices. For a shift or rotation of the excess demand curve, the value of  $\text{Exd}$  will depend on the slope and the position of the excess demand curve after the change and the values of the new equilibrium levels of  $P$  and  $X$ . Since the intersection of the excess demand curve  $\text{XD}$  and the excess supply curve  $\text{XS}$  determine equilibrium  $P$  and  $X$ , the slope and the position of the excess supply curve also influence the value of  $\text{Exd}$ .

#### Calculation Method

The calculation method, based on Yntema's formula (1932), is another way to estimate the price elasticity of export demand. For a given export price  $P$ , the quantity of exports demanded from the United States  $\text{XD}$  equals the quantity demanded by the rest of the world  $D_r$  minus the quantity supplied by the rest of the world  $S_r$ :

$$\text{XD} = D_r - S_r \quad (6)$$

where  $D_r$  and  $S_r$  represent the summation of the domestic demand and supply curves, respectively, for all other importing and exporting countries. The derivative of the demand for U.S. exports  $\text{XD}$  with respect to the U.S. price  $P$  is:

$$\frac{\partial XD}{\partial P} = \frac{\partial D_r}{\partial P_r} \cdot \frac{\partial P_r}{\partial P} - \frac{\partial S_r}{\partial P_r} \cdot \frac{\partial P_r}{\partial P} \quad (7)$$

or in terms of elasticities,

$$Exd = Ep_r \left( \frac{Ed_r \cdot D_r}{XD} - \frac{Es_r \cdot S_r}{XD} \right) \quad (8)$$

where  $Exd$  is the elasticity of demand for U.S. exports,  $Ep_r$  is the elasticity of price transmission (response of a country's price to a percentage change in the U.S. price), that is,

$$Ep_r = \frac{wP_r}{wP} \cdot \frac{P}{P_r} \quad (9)$$

$Ed_r$  and  $Es_r$  are the elasticities of domestic demand and supply, respectively, of importing and exporting countries, and  $XD$  is the level of U.S. exports. This expression follows earlier works by Tweeten (1967), Johnson (1977), and Bredahl, Meyers, and Collins (1979).

The demand component ( $Ed_r D_r/XD$ ) is an extension of the above expression, and can be disaggregated into separate expressions for consumption and inventory demand:

$$\frac{Ed_r \cdot D_r}{XD} = \frac{Ec_r \cdot C_r}{XD} + \frac{Ei_r \cdot I_r}{XD} \quad (10)$$

where  $Ec_r$  is the domestic consumption elasticity,  $Ei_r$  is the elasticity of inventory demand,  $C_r$  is the level of consumption, and  $I_r$  is the level of inventories. Substituting equation (10) into (8), the elasticity of export demand is:

$$Exd = Ep_r \left[ \frac{Ec_r \cdot C_r}{XD} + \frac{Ei_r \cdot I_r}{XD} - \frac{Es_r \cdot S_r}{XD} \right] \quad (11)$$

This expression, used in recent studies by Dunmore and Longmire (1984) and Holland and Sharples (1984), allows us to evaluate the influence of the components that make up the elasticity of export demand in more detail.

The magnitude of  $Exd$  depends on the size of the individual components that make up this parameter. The demand for U.S. exports will be more responsive to export price ( $Exd$  will be more elastic) when:

1. Importing and exporting countries are more price responsive to a change in the U.S. price (the larger the price transmission elasticity  $Ep_r$ );
2. Domestic consumption  $Ec_r$ , inventories  $Ei_r$ , and supply  $Es_r$  in importing and exporting countries are more elastic;
3. Consumption  $C_r$ , inventories  $I_r$ , and supply  $S_r$  in importing and exporting countries are greater; and
4. The volume of U.S. exports  $XD$  is smaller.

### Simulation Method

Another method for estimating the price elasticity of export demand involves obtaining dynamic price elasticities from a multiple-equation model of a commodity market. The model used in the simulation method might simply be:

1. A U.S. commodity market model which includes a single export demand equation, or
2. A multiple-region trade model in which the net trade of all trading countries determines U.S. exports.

A dynamic price export elasticity indicates how the export demand for a commodity would change over time from a change in price, after all equations in the model have adjusted to the price change. This differs from the traditional definition of an elasticity in that other things are not held constant for a given price change. This way, a dynamic elasticity is simply a dynamic multiplier expressed in percentage terms.

Pindyck and Rubinfeld (1976) define a dynamic elasticity by:

$$\text{Exd}_{t+n} = \frac{(XD_{t+n} - XD_t) \cdot P_t}{(P_t' - P_t) XD_t} \quad (12)$$

where  $XD_t$  is the level of export demand at time  $t$ ,  $XD_{t+n}$  is the level of export demand at the time  $t+n$  ( $n$  = the number of periods in the simulation),  $P_t$  is the price at time  $t$ , and  $P_t'$  is the new price level. By changing the price and simulating the model over some time, the dynamic elasticity can be calculated from the above formula. The elasticity value will partly depend on the size of  $n$ --the length of the adjustment period.

### Synthetic Method

The synthetic method has been used in constructing a number of agricultural policy simulation models at the U.S. Department of Agriculture and elsewhere (Holland and Meekhof; Holland and Sharples; Miller and Washburn; and Ray and Parvin). This is the simplest method for obtaining elasticity estimates since it does not require any data or a statistical estimation procedure. This method involves a review of elasticities reported in other studies and knowledge about the commodity market under study. The researcher first selects an elasticity value for use in a model (this may be an elasticity estimated by another researcher, a weighted average of reported elasticities, or a value that closely tracks the historical data). However, the synthetic method depends largely on the work of others. Its validity as an elasticity estimate therefore depends on the quality of information upon which it is based.

### FACTORS AFFECTING THE PRICE ELASTICITY OF EXPORT DEMAND

The excess demand schedule of the ROW ( $XD$  in fig. 1) represents the net effect of all supply and demand adjustments of importing and exporting countries. The excess supply schedule of the United States ( $XS$  in fig. 1) represents the net adjustment of its own supply and demand schedules. All of these schedules

and their implied price behavior are defined for a specific period of time. The excess demand schedule facing the United States will shift or rotate as the structure of supply and demand in importing and exporting countries changes. The structure of foreign demand could change from changes in population, income, employment, inflation, and tastes. Foreign supply shifters include changes in area, yield, weather, and technology.

In addition to these factors, changes in government policies (price supports, tariffs, quotas, and subsidies), exchange rates, and transportation costs will shift or rotate the excess demand schedule. Likewise, changing market and nonmarket forces will shift or rotate the U.S. excess supply schedule. The net effect of these changes on the elasticity of export demand will depend on the new equilibrium level of export price and quantity and the shape and position of the excess demand schedule.

### Adjustment Period

The period of adjusting to a price change is one of the most important factors in determining the magnitude of the elasticity of export demand. The longer any price change persists, the greater the effect of that price change on the amount consumed, stored, produced, and traded. Thus, the price elasticity of export demand is greater in the long run than in the short run.

A shortrun elasticity might be distinguished from a longrun elasticity by the potential sources of adjustment to price changes (Holland and Sharples, 1984, p. 1). For this report, only consumption and inventories in the countries trading in the commodity are assumed to adjust to a change in the U.S. export price in the short run. The length of time for shortrun price adjustments is typically 1 marketing year for estimates based on annual data, a period short enough that production and government policy are assumed not to change. In the long run, production, government policy, and consumption all respond to a price change. Foreign inventory adjustments are generally not included in longrun elasticity of export demand. Inventories are held primarily for speculative or pipeline purposes. Speculative stocks are considered price responsive only in the short run, while pipeline stocks are not considered price responsive (Holland and Sharples, 1984, p. 2). The price elasticity of export demand is more elastic in the long run than the short run because there are greater substitution possibilities in the long run for both consumers and producers.

### Government Policies

Domestic and trade policies of importing and exporting countries influence consumption, stockholding, and production patterns, and thus affect the elasticity of demand for U.S. exports. Government policies that fix internal prices to consumers or producers and insulate them from external price movements by various trade policy instruments reduce the responsiveness of their markets to changes in the U.S. export prices.

Import and export quotas are policy instruments that completely sever the price transmission from the export market to the internal market. These policies reduce the price transmission elasticity for these countries to zero, making the total demand for U.S. exports less elastic.



Variable levies, such as those used by the European Community (EC), affect the price elasticity in a similar manner as quotas when the world price is below the internal price. When the variable levy is added to the world price, import prices rise to the internal price level, preventing imports from expanding in response to lower world prices. When the world price rises above the internal price, variable levies are zero and world price signals can reach the domestic market unless a mechanism such as a variable subsidy offsets the price rise. In this case, the price transmission elasticity is again zero, and the elasticity of demand for U.S. exports is reduced.

Tariffs are another policy tool used by governments to protect domestic producers from import competition. Tariffs can be imposed as a specific tariff (a fixed charge per unit) or as an ad valorem tariff (a percentage of the commodity price). If the importing country imposes a specific tariff, a wedge, equal to the amount of the tariff, is forced between the price in the importing country ( $P_r$ ) and the U.S. export price ( $P$ ). For a specific tariff of amount  $T$ , the price relationship is:

$$P_r = P + T \quad (13)$$

From equation (9), the price transmission elasticity becomes:

$$E_{p_r} = \frac{P}{P + T} \quad (14)$$

which is clearly less than 1, and therefore, inelastic. The greater the amount of the tariff  $T$ , the more inelastic the price transmission and therefore the export demand.

Bilateral agreements may also affect the responsiveness of U.S. exports. If bilateral trade agreements are used so extensively that they limit total trade, then the demand for U.S. exports may become less elastic. If a country with very limited foreign exchange receives financial aid, the aid may help maintain that country's imports in the face of rising world import prices, thus reducing their price responsiveness. The more restrictive the policies that curtail the link between the domestic and world price, the less elastic demand will be for U.S. exports.

#### Domestic Structure of Trading Countries

The domestic structure of a commodity market largely determines the domestic demand and supply elasticities of trading countries and also the price elasticity of demand for U.S. exports. The greater the elasticity of demand by importers for a particular commodity (other things equal), the greater the elasticity of export demand will be for that commodity.

A number of factors determine the elasticity of domestic demand for a commodity. In general, the elasticity of demand is greater:

1. The larger the number of available substitutes,
2. The larger the portion of an individual's budget accounted for by the product, and
3. The more the product is considered a luxury item.

If a commodity (such as corn) is used as an input to produce a final product (such as meat), then a number of factors will influence the elasticity of demand for this commodity. First, the elasticity of demand for a commodity used as an input will depend on the productivity of that commodity. If the marginal product of the commodity (change in output from a unit change in the input) declines slowly as its use increases, the demand curve for the commodity will decline slowly and tend to be more elastic. Second, the elasticity of demand for a commodity used as an input in production will depend on the elasticity of demand for the final product. This is due to the derived nature of input demand--the greater the elasticity of demand for the final product, the greater the elasticity of demand for the input.

The larger the share of production costs accounted for by an input, the more elastic the demand will be for that commodity. If a particular input accounts for a large share of the total cost of a product, an increase in the price of the input will increase total cost, and therefore product price, by a relatively large amount. This will cause a relatively large drop in sales of the product, causing the demand for the input to drop.

Population, income, and consumers' tastes and preferences change and affect the elasticity of demand for a commodity. This then causes the excess demand faced by the United States for its commodities to change, affecting the elasticity of export demand.

On the supply side, the more elastic the domestic supply of a commodity in trading countries, the more elastic the elasticity of export demand will be for the commodity. The principal factors determining the elasticity of supply for a commodity include climate, available technology, and the adjustment period. Climate limits the cropping alternatives available to a country, therefore reducing the responsiveness of its producers to a price change. Adopting new production technology might increase the production of a commodity or alternative crops, thereby increasing the elasticity of supply. The longer producers have to respond to a price change, the greater (more elastic) their price response will be.

The delayed production response with respect to a fall in world price also affects the elasticity of export demand for U.S. agricultural products. This phenomenon might be termed "asymmetric production response." When world prices fall, producers in exporting and importing countries would not likely reduce production immediately. The difficulties of shortrun substitutions and large investments in infrastructure would deter any quick withdrawal of producers from the sector. In addition, many countries have self-sufficiency goals and policies designed to maintain or increase production. Thus, a decline in export price may not lead to an increase in U.S. export sales and market shares.

#### Market Share

The share of the market that a country supplies also determines the responsiveness of that country's exports to a price change. At one extreme, a country with a very small share of the world market for the commodity faces a perfectly elastic demand curve (elasticity with a value of minus infinity). This is known as the "small country case" (Grubel, 1977) where the exporter

is a price-taker and cannot influence price. A country that has a monopoly for a commodity faces a downward-sloping demand curve of the ROW. The elasticity of export demand in this case will be somewhere between zero and minus infinity. The larger a country's share of the market, other things unchanged, the smaller the elasticity of export demand for the commodity. This seems reasonable since importers of a commodity for which there are few suppliers have fewer opportunities to switch sources as a result of a price change.

Table 1 indicates the U.S. market share of world trade for selected commodities during 1960-85. The U.S. market share ranged from 26 to 53 percent for wheat, 41 to 79 percent for corn, and 65 to 94 percent for soybeans. The elasticity of export demand for these commodities should be relatively more elastic in years when the U.S. share of the market was small, and less elastic in years when its share was large, all other things unchanged.

#### ESTIMATES OF THE PRICE ELASTICITY OF EXPORT DEMAND

The following section reviews studies that provide estimates of the price elasticity of export demand for U.S. wheat, coarse grains, soybeans (and their products), rice, and cotton. The studies are grouped by commodity and reviewed according to the estimation method used in obtaining the elasticity estimates. Elasticities are also classified as either short run or long run based on the definitions in an earlier section titled "Adjustment Period."

##### Wheat Elasticities

Many studies over the past two decades examined the behavior of the international wheat market. Many of these studies attempted to estimate the price elasticity of export demand for U.S. wheat. A sampling of elasticity estimates is summarized in table 2.

##### Direct Estimation Method

Researchers have estimated directly the export demand schedule faced by the United States for its wheat. Konandreas and Schmitz (1978) estimated a model for grains that contained U.S. demand relationships for food, feed, seed, stocks, and exports. They postulated foreign (export) demand for each grain to be a function of per-capita stocks held by U.S. competitors, per-capita world production excluding the United States, concessional U.S. exports, per-capita income of five importing regions, a lagged dependent variable, and an effective U.S. export price for wheat. The price variable is the ratio between the U.S. export price for wheat and a weighted average of domestic prices of major importers (converted to U.S. dollars by an exchange rate variable). The price elasticity in this equation was -3.13. Another specification without the lagged dependent variable yielded a value of -2.95.

Chambers and Just (1981) examined the dynamic effects of exchange rate fluctuations on U.S. agriculture through an econometric model of the markets for wheat, corn, and soybeans. The econometric model consisted of 15 equations which explained domestic disappearance, inventories, production, and exports. The model was estimated by the three-stage least squares approach

Table 1--U.S. share of world trade for selected commodities, 1960-85

Year <u>1/</u>	Wheat	Corn	Sorghum	Barley	Oats	Rice	Soybeans	Cotton
				Percent				
1960	43.0	51.0	81.1	31.1	39.1	12.8	--	40.1
1961	41.8	52.7	68.3	23.4	15.1	6.5	--	32.4
1962	39.6	50.3	79.9	30.1	26.4	16.3	--	21.5
1963	41.6	55.4	70.4	19.2	7.2	17.0	--	32.2
1964	39.7	59.6	73.9	17.5	4.9	18.8	--	24.9
1965	38.7	60.2	85.0	19.5	30.2	17.1	88.2	17.9
1966	36.2	46.1	80.0	15.1	25.1	23.1	89.8	26.5
1967	40.6	53.6	78.3	11.1	13.9	25.6	87.6	24.9
1968	32.9	50.6	56.1	3.6	10.3	24.5	90.8	16.6
1969	33.0	50.3	59.2	2.4	7.8	21.2	90.0	16.3
1970	36.5	40.9	56.7	16.1	14.5	16.5	94.1	22.0
1971	33.1	56.9	48.1	6.2	15.5	22.4	93.9	18.1
1972	48.2	70.9	67.3	12.5	16.7	18.9	88.0	25.1
1973	52.6	58.4	58.1	16.1	44.0	22.2	84.5	31.3
1974	43.1	63.0	52.9	8.1	24.5	28.1	81.2	22.4
1975	47.9	71.7	55.6	3.9	15.4	24.2	73.5	17.4
1976	40.8	70.6	48.7	10.4	9.1	21.4	78.6	27.2
1977	42.0	74.9	49.8	8.1	13.0	23.6	80.2	28.7
1978	45.1	76.2	48.4	3.7	11.5	19.0	85.4	31.3
1979	43.5	78.8	71.0	7.6	4.1	23.4	81.6	40.0
1980	42.5	71.8	52.5	9.9	15.0	22.9	82.0	30.1
1981	44.7	69.6	46.9	11.0	8.7	22.0	80.3	32.5
1982	38.4	70.8	45.7	5.9	5.3	19.2	85.6	26.8
1983	35.4	71.8	49.5	9.9	2.5	17.3	86.4	35.3
1984	33.4	64.8	58.1	7.2	0.8	17.5	76.9	30.6
1985	25.9	51.2	51.4	2.1	2.1	15.3	65.4	9.6

-- = Not available.

1/ Based on aggregate of different marketing years in exporting countries.

Source: U.S. Department of Agriculture.

(3SLS) using quarterly data for 1969(I)-1977(II). 1/ The wheat export demand equation included a lagged dependent variable, the U.S. wholesale price of wheat divided by the wholesale price index, an exchange rate variable, world wheat stocks, P.L. 480 shipments of wheat, and EC threshold price that reflected tariff barriers in the EC.

1/ See Zellner (1962), Kmenta (1971), or Pindyck and Rubinfeld (1976) for a discussion of this procedure.



Chambers and Just used Special Drawing Rights (SDR) per U.S. dollar as the exchange rate variable. Each equation is estimated per capita, "to preserve the linearity of the system." Population of wheat importers rather than U.S. population would be more appropriate for converting exports to a per-capita basis. The shortrun price elasticity of U.S. wheat exports was -0.17. In this study, the short run is one quarter (3 months), and the long run is two quarters (6 months). The longrun price elasticity was -0.23, which is based on the ratio of the shortrun elasticity to 1 minus the coefficient on the lagged dependent variable. The longrun elasticity is at the low end of the range of estimates surveyed in this report.

Conway (1985) used a stochastic coefficient modeling approach on Chambers and Just's specification to examine the export demand elasticities for wheat, corn, and soybeans for the quarterly periods 1969(I)-1977(II). <sup>2/</sup> His estimates of -0.26 (short run) and -0.43 (long run) were somewhat larger than Chambers and Just's estimates. However, the estimated coefficients used in obtaining Conway's elasticities had very low t-statistics and therefore must be interpreted with caution.

Morton, Devadoss, and Heady (1984) estimated a commercial wheat export demand equation in analyzing potential grain price instability under alternative farm policies. The wheat export equation is based on work by Bredahl, Womack, and Matthews (1978). The dependent variable is per-capita commercial wheat exports, using population outside of the United States. This implies that foreign wheat consumers have identical tastes and preferences and that population has an elasticity of 1. Explanatory variables include: the average wheat price received by farmers, net of the U.S. wheat export subsidy and deflated by a trade-weighted value of the U.S. dollar; the U.S. export price of rice, net of the export subsidy and deflated; non-U.S. wheat production per capita; and U.S. P.L. 480 shipments per capita. The study used a 3SLS estimation approach for 1962-79, and obtained a shortrun estimate of -0.14, the smallest shortrun elasticity found in the survey.

Taylor and Talpaz (1979) specified a log-linear export demand equation. They obtained a shortrun estimate of -0.15 using Zellner's procedure for seemingly unrelated regressions (SUR). This estimate agrees with that obtained in the Chambers and Just study and the Morton-Devadoss-Heady study, both of which used the 3SLS estimation procedure. The price variable upon which the elasticity is based was the average U.S. farm price. Other explanatory variables included: total wheat production outside the United States, a time trend, and a dummy variable representing a shift in export demand for 1972-74.

Baumes and Meyers (1980) reported an elasticity of export demand for wheat of -0.35 which is the same value obtained by Kost, Schwartz, and Burris who used the simulation method. Their elasticity was based on the average wheat price received by U.S. farmers less the U.S. export payment rate on wheat. Other explanatory variables included: a weighted average U.S. feed grain price expressed as a ratio to the wheat price; the U.S. export price of rice less the average export payment rate; U.S. P.L. 480 and aid exports of wheat and flour; and wheat production and stocks in Europe, Canada, Australia, and less developed countries (LDC's). The dependent variable is U.S. wheat exports

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<sup>2/</sup> See Swamy and Tinsley (1980) for a discussion of this approach.

Table 2--Price elasticities of export demand for U.S. wheat

Study	Period	Method	Elasticity	
			Short run	Long run
Konandreas and Schmitz (1978)	1955-72	Estimation (OLS)	-3.13 <u>1/</u>	--
Taylor and Talpaz (1979)	1960-74	Estimation (SUR)	-.15	--
Baumes and Meyers (1980)	1951-76	Estimation (OLS)	-.35	--
Gallagher, Lancaster, Bredahl, and Ryan (1981)	1960-74	Estimation (OLS)	-.41	--
Chambers and Just (1981)	1969(I) 1977(II)	Estimation (3SLS)	-.17	-0.23
Gadson, Price, and Salathe (1982)	1963-78	Estimation (OLS)	-.21	--
Morton, Devadoss, and Heady (1984)	1962-79	Estimation (3SLS)	-.14	--
Conway (1985)	1969(I)- 1977(II)	Estimation (SC) <u>2/</u>	-.26	-.43
Johnson (1977)	1970 base	Calculation	--	-6.72
Miller and Washburn (1978)	1976 base	Calculation	--	-5.00
Bredahl, Meyers, and Collins (1979)	1972/73- 1975/76	Calculation	--	-1.67 <u>3/</u>
Burt, Koo, and Dudley (1980)	--	Calculation	-2.50	--
Webb and Blakely (1982)	--	Calculation	-1.05	--
Paarlberg (1983)	1960-75	Calculation	--	-1.82
Dunmore and Longmire (1984)	1980/81- 1982/83	Calculation	--	-.84
Honma and Heady (1984)	1964-78	Calculation	-.44	--
Liu and Roningen (1985)	1984 base	Calculation	--	-2.30
Gardiner (1986)	1967-80	Calculation	--	-.81

Continued--

Table 2--Price elasticities of export demand for U.S. wheat--Continued

Study	Period	Method	Elasticity	
			Short run	Long run
Kost, Schwartz, and Burris (1979)	1960-75	Simulation	-0.35	-0.35
Holland and Sharples (1984)	1979/80-1981/82	Simulation	-.70	--
Green and Price (1984)	1986	Simulation	-.54	--
Seeley (1985)	1985 base	Simulation	-.81	-1.49
Ray and Parvin (1978)	--	Synthetic	-.50	-1.50
Holland and Sharples (1981)	--	Synthetic	-.50	--

-- = Not available.

1/ A value of -2.95 was obtained when the lagged dependent variable was dropped.

2/ Stochastic coefficient method.

3/ A value of zero was obtained when the price transmission elasticity for the rest of the world was set to zero and a value of -5.50 was obtained when the price transmission elasticity was set to 1.

less P.L. 480, aid, and exports to centrally planned economies, expressed per capita using world population less population in the United States and centrally planned countries.

#### Calculation Method

Johnson (1977) was one of the earliest to estimate the price elasticity of demand for U.S. wheat exports using the calculation method. Using a variation of the formula proposed by Tweeten (1967), Johnson reported a longrun elasticity of export demand of -6.72. This estimate was based on 1970 market shares and assumed identical domestic demand and supply elasticities for all countries that import U.S. wheat (-0.40 for demand and 0.20 for supply). These elasticities were net of cross-price relationships between commodities. Johnson does not report the source of the supply and demand elasticities used in his calculation. Therefore, it is not clear whether the elasticities account for impacts of government programs, transport costs, and other influential factors. The study also assumed a price transmission elasticity of 1, implying free trade.

Given the restrictive trade and domestic policies pursued by many importing nations, this suggests that the study overestimated the elasticity of export demand. Webb and Blakely (1982) further contend that Johnson's high elasticity value also results from his assumptions regarding supply and demand

elasticities for individual countries and regions of the world. Johnson's elasticities were 3 to 10 times greater than those estimated by Webb and Blakely. Webb and Blakely obtained an elasticity estimate of -1.05. Using Webb and Blakely's elasticities in Johnson's formula yielded an elasticity of excess demand for U.S. exports of only -1.03.

Miller and Washburn (1978) used the approach introduced by Tweeten and refined by Johnson to compute export demand elasticities for various U.S. agricultural products. They obtained a longrun wheat elasticity estimate of -5.0, which falls below Johnson's estimate but above most estimates. Miller and Washburn based their estimate on 1976 prices and quantities but provided no information on which countries were used in constructing the elasticity estimate.

Bredahl, Meyers, and Collins (1979) argued that Tweeten and Johnson did not sufficiently account for domestic and trade policies pursued by importing countries distorting the transmission of world prices into their domestic market. Their computations included a price transmission elasticity term that measured the change in the domestic prices of importing countries in response to changes in world price. The price transmission elasticity varied from zero (restricted trade) to 1 (free trade). The study covered five commodities and included six regions. Longrun export demand elasticities were computed for three alternative price transmission elasticity scenarios. Their longrun elasticity estimates ranged from zero to -5.50. The estimate they considered "...the closest approximation to the real world" was -1.67 which is reported here. This study improves on the Johnson and Tweeten studies; however, the price transmission elasticity was based on educated guesses. Directly estimating price transmission elasticities using statistical estimation would more accurately measure how U.S. prices affect foreign prices.

Paarlberg's (1983) U.S. export demand elasticity for wheat of -1.82 was a weighted aggregate of domestic excess demand and excess supply elasticities for three importers and three exporters. Excess demand and supply schedules for five of the six regions were based on their respective demand and supply schedules and the world price. The excess demand schedule for an aggregated ROW region was directly estimated. All schedules were estimated using 2-year averages of annual data for 1960 through 1975. An instrumental variable method (IV) corrected for first-order serial correlation was used. Paarlberg's approach assumed government policies to be endogenous and production to respond instantaneously. His elasticity estimate of -1.82 should therefore be interpreted as an intermediate or longrun estimate.

Following the approach of Bredahl, Meyers, and Collins, Dunmore and Longmire (1984) accounted for trade restrictions in their elasticity calculation by incorporating elasticities of price transmission. They assigned price transmission elasticities to seven countries and regions, according to the degree to which they perceived a government's trade policies insulating domestic prices from world prices. Using these price transmission elasticities, elasticities of export demand and supply from other studies, and market-share weights, they found the U.S. export demand elasticity for wheat to be price inelastic at -0.84. While the estimate is listed in the table as a longrun elasticity, it is based on a combination of shortrun and longrun factors. While including stock adjustments suggests a shortrun period, using production elasticities implies a longrun framework.



In a related study, Dunmore (1984) examined the sensitivity of the export demand elasticity to changes in the transmission elasticities. Following the approach of Bredahl, Meyers, and Collins, Dunmore imposed a price transmission elasticity of 1.0 for all countries, implying free trade. His elasticity estimate for U.S. wheat exports more than tripled from -0.84 to -2.64 in moving from restrictive trade to free trade.

Liu and Roningen (1985) obtained a longrun U.S. wheat export demand elasticity of -2.3 based on a 27-region, 20-commodity grain-oilseeds-livestock (GOL) model of the world. In its most simple form, each importing and exporting region was represented by a domestic demand and supply schedule. The domestic supply and demand elasticities were either estimated with annual time series data from 1960 to 1980 or synthesized from other studies. The estimated elasticities were based on a world price (the U.S. export price) and so implicitly accounted for the price transmission elasticity. The wheat elasticity was a weighted average of the domestic supply and demand elasticities across the 27 regions, using their respective supply and demand quantities relative to U.S. wheat exports as weights.

Gardiner (1986) obtained an export demand elasticity for U.S. wheat of -0.81 based on an econometric model of the markets for wheat, corn, and soybeans which was developed to analyze the effects of alcohol fuel production. The elasticity was calculated from supply, demand, and price-transmission elasticities which were estimated over the period 1967-80 for the European Community, and an aggregate rest-of-the-world region. The elasticity is listed as a longrun estimate since it includes supply adjustments to a price change. However, since the adjustment period is only 1 year, the elasticity might be more appropriately called an intermediate-run elasticity.

Two other variations of the calculation approach estimated the elasticity of export demand for U.S. wheat. One approach views elasticity estimates as a weighted aggregate of regional export demand elasticities facing the United States. The weights normally represent the market share of the importing region in total U.S. exports.

Using this approach, Gallagher, Lancaster, Bredahl, and Ryan (1981) estimated shortrun price elasticity of export demand for wheat at -0.41. Their elasticity was a weighted sum of the estimated elasticities of three individual regions--Japan, Western Europe, and an aggregate of LDC's. The estimates were obtained from OLS estimation and covered 1960-74. The weights were used in the 1974 market shares of U.S. wheat exports to these regions. The individual regional elasticities were obtained from a combination of approaches. For Japan and the LDC's, the regional export demand elasticities were estimated directly from export equations. Because direct estimates did not yield satisfactory results for Western Europe, they estimated a marginal share of U.S. wheat exports relative to Western European total wheat imports and used this relationship along with their domestic demand elasticities to obtain the implied regional export demand elasticity.

Burt, Koo, and Dudley (1980) used an estimate of the export demand elasticity for wheat of -2.5 in developing a stochastic dynamic programming model to estimate optimal strategies for U.S. wheat reserve policy. The elasticity was obtained by aggregating regional demand elasticities estimated by Konandreas

(1976) in his econometric analysis of U.S. grain exports. Average quantities exported from the United States to individual regions were used as weights. The elasticity was used to transform a world price forecasting equation (derived from a Box-Jenkins time series analysis) into an export demand-forecasting equation.

A second variation of the calculation method establishes trade flow patterns among trading partners and calculates an elasticity of export demand based on the elasticities of substitution. Honma and Heady (1984) used a variation of the Armington model to establish commercial trade flow patterns for a combination of 10 importers and 5 exporters. The elasticities of substitution derived from the trade flow equations were then used to calculate a shortrun estimate of -0.44 for the price elasticity of U.S. wheat exports. The trade flow equations were estimated using the SUR technique for 1964-78. The elasticity estimate, however, needs to be interpreted with caution. There were insignificant responses to price when supplies for half the importing regions were chosen. Also, the hypothesis of the equality of substitution between all pairs of exporters was rejected in some regions. Therefore, this analysis suggests the Armington approach may not be appropriate for some markets.

#### Simulation Method

A few studies estimated the export elasticity of demand for wheat using the simulation approach. Kost, Schwartz, and Burris (1979) used the Foreign Demand and Competition Division (FDCD) world trade forecasting system to obtain a shortrun arc elasticity of export demand for U.S. wheat of -0.35. <sup>3/</sup> This elasticity estimate was based on a two-commodity (wheat and coarse grains), 19-region net-trade model that accounted for the interaction between the major trading countries for each of the commodities.

The net-trade model consists of a system of export supply and import demand functions by country and commodity, and was solved simultaneously for net trade (net exports and net imports) and world price levels. The export supply and import demand functions were specified as functions of own price, other commodity prices, production, income, population, and other demand shifters and were estimated using OLS for 1960-74. The study also reported a longrun elasticity of -0.35, based on 5-year cumulative impact multipliers that resulted from only a first-period shock. To estimate elasticities, the authors shocked the intercept term of the U.S. export supply schedule for wheat, thereby shifting the schedule to a new equilibrium point on the ROW import demand schedule. They calculated an arc elasticity from the two equilibrium points.

Green and Price (1984) obtained elasticity estimates for wheat and other crops using the Food and Agricultural Policy Simulator (FAPSIM) developed by Gadson, Price, and Salathe (1982). FAPSIM, an annual econometric model of the U.S. agricultural sector, establishes a simultaneous price-quantity equilibrium solution for a set of individual commodity models developed for selected commodities: beef, pork, dairy, chicken, eggs, turkey, corn, oats, barley, grain sorghum, wheat, soybeans, and cotton.

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<sup>3/</sup> An arc elasticity is measured between two points along a curve.

To estimate elasticities using the simulation method, Green and Price initially solved the model for 1980-88 to establish a baseline. Then all commodity prices and quantities were constrained to equal their baseline values. Wheat prices were then raised by 10 percent in 1986, holding all other prices constant. Arc elasticities were then obtained by calculating the percentage change in U.S. wheat exports in response to the price changes. This procedure resulted in a price elasticity of export demand for wheat in 1986 of -0.54. Note however, given the model structure, this result is relevant only to the extent that the average wheat price received by farmers remains above the loan rate and below the reserve release level. At prices below the loan rate and above the release levels, the market price is ineffective (perfectly elastic at the loan rate).

Seeley (1985) used the International Institute for Applied Systems Analysis (IIASA) world agricultural model to obtain elasticity estimates for selected commodities. Whereas FAPSIM is a model of the U.S. agricultural sector with a single export sector, the IIASA model includes 20 major countries or regions. The system includes nine agricultural commodities and a nonagricultural commodity. The nonagricultural category includes all economic goods outside agriculture except credit and other financial institutions. Modifications to the system allow elasticities of domestic supply, demand, price transmission, and net trade to be estimated. Seeley determined export demand elasticities faced by the United States through various scenarios of the IIASA system. The system initially operated with exogenous, fixed world prices for a 10-year base run beginning in 1985. Next the world wheat price was dropped by 10 percent and held at that lower level. The system was again run for 10 years beginning with 1985, using the lower world wheat price. The resulting changes in domestic supply, demand, and price were then used to obtain the elasticity of export demand. The own-price elasticity of net import demand for U.S. wheat was calculated to be -0.81 in the first year after a price shock. This essentially represents a shortrun estimate in that production does not respond in the first period. When production from both the Southern and Northern Hemispheres responds in the second year (the long run), the export demand elasticity for U.S. wheat increased to -1.49.

Holland and Sharples (1984) used a combination of the calculation and simulation methods in a spatial equilibrium trade model--the Generalized Transportation Problem (GTP)--to obtain a shortrun elasticity of export demand for U.S. wheat of -0.7, based on the trade levels observed during 1979/80-1981/82. The estimate was obtained from a 20-region world wheat trade model that included bilateral agreements, constant transport costs, tariffs, subsidies, and indirect foreign exchange constraints as well as the usual supply, demand, and stocks equations. The U.S. export demand elasticity was obtained by first finding an equilibrium solution that approximated the net trade position for each region in the base period. Next they varied the quantity of wheat shipped from the United States to obtain alternative world trade equilibria. As the quantity exported by the United States rose, the U.S. export price fell. A plot of these export prices and quantities traced out the U.S. export demand curve: the United States exported around 43 million tons of wheat during the 1979/80-1980/81 base period. The U.S. export demand curve in that vicinity had a price elasticity of about -0.7.



The simulation approach is a relatively new method in estimating the price elasticity of demand for U.S. exports. The approach generally overcame some of the limitations of the computation procedure. At least one of the studies (Holland and Sharples) accounted for transport costs. Holland and Sharples, and Seeley allowed for barriers to trade in their computation. In addition, their disaggregation was detailed enough to account for the behavior of most of the important trading countries. Three of the studies indicated remarkable similarities in their shortrun elasticity estimates for U.S. exports of wheat.

### Synthetic Method

Two studies obtained elasticity estimates from other studies or from the accumulated experience of commodity analysts. Ray and Parvin (1978) used synthetic elasticities to construct POLYSIM, an annual simulation model of the U.S. agricultural sector. In a review of empirical work from a number of models based on data beginning as early as 1921 and going up to 1973, they found shortrun wheat export elasticities ranging from -0.33 to -0.64. They selected -0.50 as their shortrun estimate and chose -1.50 as their longrun estimate.

Holland and Sharples (1981) used the same shortrun wheat export elasticity (-0.50) as Ray and Parvin in WHEATSIM, an annual simulation model of the U.S. wheat market. The elasticity is used in an export demand equation in constant elasticity form. The equation also contains a growth component, reflecting the possibility of increasing income and population, and a random-shock term to approximate foreign supply fluctuations.

### Evaluation

No well-defined patterns emerge when comparing wheat export demand elasticity estimates by estimation period or method. Longrun estimates averaged nearly three times larger than shortrun estimates.

The shortrun elasticity of export demand for U.S. wheat ranged from -0.14 to -3.13, averaging -0.72. Excluding the high and low estimates yielded a slightly lower average elasticity of -0.60. Fourteen of the 17 estimates (or 82 percent) were in the inelastic range (less than 1 in absolute value). The longrun U.S. export demand elasticity for wheat ranged from -0.23 to -6.72, averaging -1.93 for all estimates surveyed. Dropping the high and low values of the range resulted in a slightly lower average estimate of -1.62. Seven of the 12 longrun elasticity estimates (58 percent) were in the elastic range (greater than 1 in absolute value).

### Coarse Grains Elasticities

This section reviews elasticities of export demand for U.S. exports of corn, sorghum, feed grains, and total coarse grains. <sup>4/</sup> The studies are examined by estimation method for the individual commodities and commodity groups. Studies

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<sup>4/</sup> Feed grains include corn, barley, oats, and sorghum; coarse grains include feed grains plus rye. However, the terms in this report are used interchangeably since most studies do not make a distinction.

discussed in the section on wheat elasticities that also reported a coarse grain elasticity are only briefly mentioned here. Table 3 summarizes some studies containing estimates of the price elasticity of export demand for U.S. coarse grains.

#### Direct Estimation Method

Meilke (1975) specified a six-equation simultaneous model of U.S. feed grain demand. His export equation was defined as the quantity of feed grains commercially exported during the crop year. Explanatory variables included an index of prices received by farmers for feed grains, an index of wholesale price of 11 high-protein feeds, P.L. 480 feed grain exports, an index number of animal units fed in Japan and seven European countries, an index of feed grain production per animal in Japan and seven European countries, and July 1 stocks of feed grains in three major exporting countries. The export demand equation was estimated with a 2SLS approach, using crop year data from 1945 through 1972. His shortrun elasticity estimate for feed grain exports was -1.20, based on an index of feed grain prices received by U.S. farmers. Feed grain production in the major importing countries as well as stocks of principal exporters was assumed to be known with certainty and therefore treated as exogenous in the model.

Bredahl, Womack, and Matthews (1978) estimated a restricted-coefficients model for U.S. corn export demand. The price variables were the U.S. farm price of corn divided by the U.S. farm price of soybeans, and the European Community's threshold price of corn divided by the U.S. farm price of soybeans and deflated by the U.S. dollar/SDR exchange rate. Other explanatory variables included: an index of livestock production of principal importing countries; exports of competing countries' production and stocks in the EC; non-U.S. corn imports by the Soviet Union; and subsidized rice fed to Japan's livestock. They estimated four different equations, alternatively restricting the coefficients for the variables of competing exporters, total EC supply, and non-U.S. exports to the Soviet Union at a value of 1. They estimated the model for the crop years 1962/63 through 1974/75 using OLS. U.S. commercial corn exports were relatively inelastic with respect to the U.S. farm price of corn (-0.31). Sequentially relaxing the restrictions on the coefficients yielded price elasticities ranging from -0.35 to -0.38.

U.S. sorghum exports were similarly tested. The price variables included the ratio of the sorghum price to the corn price and the soybean price. Other regressors included Japanese livestock production, sorghum and corn exports of competitors, and EC corn supply. Sorghum exports were very responsive to price (elasticity = -2.26). Other specifications yielded price elasticities ranging from -2.16 to -2.36.

For their analysis of the effects of exchange rate changes on U.S. agriculture, Chambers and Just (1981) estimated a corn export equation as part of a larger system. A 3SLS estimation on quarterly data for 1969(I) to 1977(II), yielded shortrun price elasticity of -0.47. This shortrun estimate, along with the coefficient on the lagged dependent variable, yielded a longrun estimate of -0.63.

Table 3--Price elasticities of export demand for U.S. coarse grains

Study	Period	Method	Elasticity	
			Short run	Long run
<u>Coarse Grains</u>				
Meilke (1975)	1945-72	Estimation (2SLS)	-1.20	--
Shuib and Menkhaus (1977)	1950-73	Estimation (2SLS)	-1.51	--
Collins (1977)	1959-75	Estimation (OLS)	-.30	--
Dixit (1984)	1960-81	Estimation (IV) <u>1</u> /	-.64	--
Johnson (1977)	1970 base	Calculation	--	-10.18
Dunmore and Longmire (1984)	1980/81- 1982/83	Calculation	--	-1.51
Liu and Roningen (1985)	1981 base	Calculation	--	-3.30
Kost, Schwartz, and Burris (1979)	1960-75	Simulation	-.46	-.86
Seeley (1985)	1985 base	Simulation	-.84	-1.70
Ray and Parvin (1978)	--	Synthetic	-.50	-1.50
<u>Corn</u>				
Bredahl, Womack, and Matthews (1978)	1962/63- 1974/75	Estimation (OLS)	-.31	--
Baumes and Womack (1979)	1962/63 1975/76	Estimation (OLS)	-.16	--
Baumes and Meyers (1980)	1962/63- 1975/76	Estimation (OLS)	-.19	--
Chambers and Just (1981)	1969(I)- 1977(II)	Estimation (3SLS)	-.47	-.63
Gadson, Price, and Salathe (1982)	1967-78	Estimation (OLS)	-.29	--
Green and Hoskin (1982)	1962-79	Estimation (OLS)	-.17	--
Conway (1984)	1969(I)- 1977(II)	Estimation (SC) <u>2</u> /	-.32	-.41

Continued--

Table 3--Price elasticities of export demand for U.S. coarse grains--Continued

Study	Period	Method	Elasticity	
			Short run	Long run
Bredahl, Meyers, and Collins (1979)	1972/73-1975/76	Calculation	--	-1.31 <u>3/</u>
Gardiner (1986)	1967-80	Calculation	--	-1.18
Green and Price (1984)	1986 base	Simulation	-.40	--
Holland and Meekhof (1979)	--	Synthetic	-.60	--
Holland and Sharples (1982)	--	Synthetic	-.50	--
Orden (1984)	--	Synthetic	-.50	--
<u>Sorghum</u>				
Bredahl, Womack, and Matthews (1978)	1962/63-1975/76	Estimation (OLS)	-2.26	--
Baumes and Meyers (1980)	1962/63-1975/76	Estimation (OLS)	-2.11	--
Gadson, Price, and Salathe (1982)	1961-78	Estimation (OLS)	-1.23	--
Green and Hoskin (1982)	1962-79	Estimation (OLS)	-.89	--
Grant and Hoskin (1984)	1959-81	Estimation (3SLS)	-1.76	--
Bredahl, Meyers, and Collins (1979)	1972/73-1975/76	Calculation	--	-2.36 <u>4/</u>
Green and Price (1984)	1986 base	Simulation	-1.17	--

-- = Not available.

1/ Instrumental variable method corrected for first-order serial correlation.

2/ Stochastic coefficient method.

3/ A value of -0.09 was obtained when the price transmission elasticity for the rest of the world was set to zero and a value of -3.13 was obtained when the price transmission was set to 1.

4/ A value of -0.29 was obtained when the price transmission elasticity for the rest of the world was set to zero and a value of -2.55 was obtained when the price transmission was set to 1.



Green and Hoskin (1982) obtained export demand elasticities for corn and sorghum as part of a U.S. crops model study that included feed grains, wheat, and soybeans. The corn export demand schedule, estimated by OLS, included data for the years 1962-1979. In computing the elasticities, however, they used the mean of the last 5 years of data (1975-1979) rather than the entire range. They argued that production and marketing environments had changed so greatly over the study period that including information from early years would be misleading. The shortrun elasticity estimate of export demand for U.S. corn was -0.17, comparable to that obtained by Baumes and Womack. Their sorghum elasticity estimate (-0.89) was the lowest among the studies surveyed.

Grant and Hoskin (1984) used an export equation (estimated by 3SLS) for 1959-81 to determine the export demand elasticity for sorghum. Explanatory variables included: the ratio of the season average price of sorghum to corn; the U.S. dollar/Special Drawing Right exchange rate variable (following the approach of Chambers and Just); an index of livestock numbers in Japan, South Korea, Israel, and Mexico; an index of U.S. sorghum exports to India; and the number of cattle on feed on October 1 in four U.S. States. The estimation yielded a shortrun elasticity of -1.76, which falls around the middle of the range of estimates reported.

Dixit (1984) estimated a shortrun export demand elasticity for U.S. coarse grains exports of -0.64. His estimate covered 1960-81, and was estimated using an instrumental variable approach (IV) corrected for first-order serial correlation. The estimate was obtained from a partial-equilibrium, policy-endogenous coarse grains model that used the residual-supplier concept discussed by Bredahl and Green (1983). The U.S. export demand elasticity was the weighted sum of total world import demand elasticity (-0.23) and the export supply elasticity of competing exporters (0.11). Dixit also used the U.S. price as a proxy for world price.

Table 3 contains other estimates of export demand elasticities for U.S. coarse grains and its component products including studies by Collins (1977), Baumes and Womack (1979), Baumes and Meyers (1980), Gadson, Price, and Salathe (1982), and Conway (1985).

### Calculation Method

Three studies reported elasticity of export demand for total coarse grains or feed grains using the calculation method (table 3). All were longrun estimates. Johnson (1977) used domestic demand elasticities of -0.40 and supply elasticities of 0.20 for all countries that import U.S. feed grains to arrive at a longrun estimate of -10.18 for the elasticity of export demand. This estimate is more than three times larger than any other estimate reported here. The elasticity estimate reflects a free trade environment rather than the existing market structure because the calculation assumed a price transmission elasticity of 1.

Dunmore and Longmire (1984) calculated -1.51 as the longrun foreign demand elasticity facing the United States, which is similar to the synthetic value used by Ray and Parvin in constructing the POLYSIM model. Their estimate was based on domestic supply and demand elasticities for each of six regions. The elasticity of export demand for coarse grain was more elastic than that for



wheat (-0.84). In a related study, Dunmore (1984) relaxed the assumption of restrictive trade and his coarse grains export demand elasticity (-3.43) was more than double the original estimate (-1.50).

Liu and Roningen's (1985) longrun export elasticity for coarse grains was -3.30. This was calculated as a weighted average of domestic supply and demand elasticities for 20 regions. Since their domestic supply and demand elasticities were based on a world price denominated in U.S. dollars, the export demand elasticity implicitly accounts for the trade and domestic policies of trading countries.

Bredahl, Meyers, and Collins (1979) reported longrun export demand elasticities for corn and sorghum. The corn elasticities varied from -0.09 for the most restrictive case to -3.13 for the free trade case. The estimate thought to be the closest to the real world for corn was -1.31 (which is smaller than the elasticity of -1.67 reported for wheat exports under a similar scenario). The lower elasticity for corn is consistent with corn's larger share of world trade compared with that of wheat exports. However, lower trade restrictions and available substitutes would tend to lead to higher export demand elasticity for corn relative to wheat. The longrun sorghum export demand elasticity was higher than that for corn or wheat for all three scenarios, ranging from -0.29 to -2.55. The most "realistic" sorghum elasticity was -2.36.

Gardiner (1986) obtained a longrun export demand elasticity for corn that was in the elastic range (-1.18). It was calculated from supply, demand, and price-transmission elasticities that were estimated over the period 1967-80 for the European Community and a rest-of-the-world region. The elasticity was only slightly smaller than the estimate calculated by Bredahl, Meyers, and Collins but significantly larger than elasticities obtained by the direct estimation method.

### Simulation Method

Kost, Schwartz, and Burris (1979) used the two-commodity FDCD world trade forecasting system to obtain shortrun and longrun elasticities of export demand for coarse grains of -0.46 and -0.86, respectively. Green and Price (1984), using FAPSIM, obtained a shortrun export elasticity estimate of -0.40 for corn and -1.17 for sorghum. With 1984 production shares used as weights, this implies a total coarse grains elasticity of -0.44. Seeley (1985) reported a shortrun export demand elasticity for coarse grains of -0.84 from simulating the IIASA model. The longrun (second year) estimate of -1.70 was about twice the magnitude of the shortrun estimate.

### Synthetic Approach

Synthetic elasticities are also used in constructing coarse grains models and for market analysis. Ray and Parvin (1978) used a shortrun export elasticity of demand for coarse grains of -0.50 and a longrun value of -1.50 in POLYSIM. Holland and Sharples (1982) used a shortrun elasticity for U.S. corn exports of -0.50 in FEEDSIM, a stochastic simulation model of the corn and soybean markets. Sharples (1982) used this same value in a two-country, single-commodity model to examine export subsidies for corn. Orden (1984) similarly

used a shortrun export demand elasticity of -0.50 in analyzing the relative effects on the world corn market of macroeconomic versus sectoral factors.

### Evaluation

Table 4 reviews estimates of the elasticity of demand for U.S. coarse grain exports. The shortrun elasticity estimates ranged from a low of -0.30 to -1.51 for coarse grains, -0.16 to -0.60 for corn, and -0.89 to -2.26 for sorghum. The longrun elasticity estimates ranged from -0.86 to -10.18 for coarse grains and -0.41 to -1.31 for corn. There was only one longrun estimate (-2.36) reported for sorghum.

The average shortrun estimate (average value excluding the high and low estimates in parentheses) was -0.78 (-0.73) for coarse grains, -0.36 (-0.35) for corn, and -1.57 (-1.57) for sorghum. The longrun estimates averaged -3.18 (-2.00) for coarse grains and -0.88 (-0.91) for corn. The value -2.36 was the only longrun estimate for sorghum. Five of the seven shortrun estimates for coarse grains were in the inelastic range (less than 1 in absolute value) while only one longrun estimate was inelastic. All shortrun estimates for corn were inelastic as well as two of the four longrun estimates. All but one of the elasticity estimates for sorghum were elastic. Therefore, the shortrun price elasticity of export demand appears to be inelastic for corn and total coarse grains and elastic for sorghum. For the long run, both total coarse grains and sorghum appear to be price elastic. The lack of empirical evidence for corn prevents any conclusion on the magnitude of the longrun price responsiveness of corn.

Elasticity estimates for corn appear low when compared with those for total coarse grains, given that corn constitutes around 66 percent of total coarse grains trade. Furthermore, the substitution possibilities for an individual commodity (such as corn) are greater than those for an entire commodity group (such as coarse grains), implying a larger price elasticity for the individual commodity. The discrepancy in the estimates might be due to aggregation problems associated with estimating equations for commodity groups.

There are no clear patterns in elasticity estimates based on the estimation period. All elasticities obtained by the calculation method were longrun estimates and all were greater than 1 (elastic) in absolute value. Few longrun estimates were available from studies using direct estimation procedures.

### Soybeans and Their Products Elasticities

This section discusses the price elasticities of export demand for U.S. soybeans, soybean meal, and soybean oil. The section covers some studies done between 1971 and 1984. The elasticity estimates are listed in table 4. The studies are categorized according to method of estimation.

#### Direct Estimation Method

Houck, Ryan, and Subotnik (1972) estimated a statistical model for the U.S. market for soybeans and its products. The model contained behavioral equations for soybeans, soybean meal, and soybean oil. Soybean exports were

Table 4--Price elasticities of export demand for soybeans,  
soybean meal, and soybean oil

Study	Period	Method	Elasticity			
			Soybeans		Soybean	Soybean
			Short run	Long run	meal 1/	oil 1/
Houck, Ryan, and Subotnik (1972)	1946-66	Estimation (OLS)	-0.53	--	-0.28	-0.61
		Estimation (2SLS)	-.54	--	-.22	-.62
		Estimation (3SLS) <sup>2/</sup>	-.67	--	-.24	-.43
		Estimation (3SLS)	-.68	--	-.27	-.63
Matthews, Womack, and Hoffman (1971)	1954-70	Estimation (3SLS)	-.61	--	-.77	--
Baumes and Meyers (1980)	1955-75	Estimation (OLS)	-1.99	--	-.60	--
Meilke and Young (1979)	1967(IV)	Estimation (OLS)	-1.81	--	-.64	--
	1976(IV)					
Meyers and Hacklander (1979)	1955-77	Estimation (OLS)	-2.00	--	-.61	-1.00 <sup>3/</sup>
Chambers and Just (1981)	1969(I)	Estimation (3SLS)	-.20	-0.29	--	--
	1977(II)					
Helmberger and Akinyosoye (1984)	1948/49-	Estimation (3SLS)	-.14	--	--	--
	1977/78					
Gadson, Price, and Salathe (1982)	1961-79	Estimation (OLS)	-.19	--	-.51	-.24
Green and Hoskin (1982)	1955-79,	Estimation (OLS)	-1.10	--	-.55	--
	1975-79 <sup>4/</sup>					
Johnson (1977)	1970 base	Calculation	--	-2.80	--	--
Bredahl, Meyers, and Collins (1979)	1972/73-	Calculation	--	-.47	--	--
	1975/76					
Dunmore and Longmire (1984)	1980/81-	Calculation	--	-.97	--	--
	1982/83					
Gardiner (1986)	1967-80	Calculation	--	-1.03	--	--
Green and Price (1984)	1986 base	Simulation	-.25	--	-.39	-.27
Ray and Parvin (1978)	--	Synthetic	-.65	-1.95	--	--
Holland and Meekhof (1979)	--	Synthetic	-1.00	--	--	--
Holland and Sharples (1982)	--	Synthetic	-1.00	--	-.60	-2.00

-- = Not available.

<sup>1/</sup> Soybean meal and oil elasticities are shortrun estimates.

<sup>2/</sup> Involves a linear approximation of the price ratios in using the linear terms in a Taylor series expansion.

<sup>3/</sup> Synthetic value.

<sup>4/</sup> First range of years for soybeans, second range for soybean meal; mean of last 5 years used for computing elasticities.

assumed to be a function of: the ratio of the U.S. prices of soybeans to the price of soybean meal to reflect the importers' ability to substitute between purchases of beans and meal; feed grain production per livestock unit in importing countries, which equals a per-capita income effect; and a trend variable to capture changes in production technology. Soybean meal exports are expressed as a function of: the ratio of the U.S. price of soybean meal to the United Kingdom's price of linseed meal (a competing oilseed meal); feed grain production per livestock unit in importing countries; world imports of other oilseed meals less U.S. soybean meal exports; and a cumulative trend variable to reflect changes in livestock feeding practices abroad. For U.S. soybean oil exports, explanatory variables included: the ratio of the U.S. soybean oil price to the European price of groundnut oil; an index of national income in countries importing U.S. soybeans and its products; P.L. 480 shipments of vegetable oils; olive oil production in Mediterranean countries; other vegetable oils in world trade; and a dummy variable for 1975 to account for Spanish trade restrictions.

Structural coefficients were obtained using several estimation methods--OLS, 2SLS, and 3SLS. An alternative set of 3SLS estimates was obtained using a technique which involves a linear approximation of the price ratios using linear terms in a Taylor series expansion. <sup>5/</sup> The estimation technique is designated by 3SLSR. Data for crop years 1946-66 were used in obtaining the estimates. Price elasticities were calculated at the mean for each equation and for the estimation methods. The shortrun price elasticities varied slightly among methods. For soybean exports, the price elasticity ranged from -0.53 (OLS) to -0.68 (3SLS); for soybean meal exports, -0.22 (2SLS) to -0.28 (OLS); and for soybean oil exports, -0.43 (3SLSR) to -0.63 (3SLS). The elasticity estimates were similar across estimation methods though no statistical test was performed to evaluate whether they were significantly different from one another.

Meyers and Hacklander (1979) developed an econometric model of the U.S. soybean market to analyze effects of supply and demand shocks in the domestic and foreign markets. The model was estimated by OLS over 1955-77. The export demand equation for soybeans included as explanatory variables: the U.S. average price of soybeans at Decatur, deflated by the U.S. dollar/SDR exchange rate; the soybean crush value (price of soybean meal times meal yield plus price of soybean oil times oil yield) deflated by the exchange rate variable; a weighted average of the U.S. farm price of corn and the EC threshold price; a separate variable for the U.S. dollar/SDR exchange rate; an index of livestock production in the EC-6, the United Kingdom, and Japan; and competing exports from Brazil. The price elasticity of demand for U.S. soybean exports was -2.00. The equation is appealing in its inclusion of competing prices and an exchange rate variable. However, including a separate exchange rate variable in addition to deflating the price by the same variable entails double-counting of the influence of this variable. Meyers and Hacklander also reported elasticity estimates for soybean meal (-0.61) and soybean oil (-1.00). The soybean meal estimate was obtained from an OLS regression equation with features similar to the soybean equation. The soybean oil

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<sup>5/</sup> See J. Johnston (1963, p. 267) for a more detailed discussion of this technique and Houck, Ryan, and Subotnik (1972, p. 83) for an application.



elasticity was not estimated but represents a synthetic value, although no explanation was given for the value chosen.

In a closely related study, Baumes and Meyers (1980) estimated similar export demand equations for soybean and soybean meal. The equations were estimated over the 1955-75 period, using OLS. The price elasticities of export demand they obtained were -1.99 and -0.60 for soybeans and soybean meal, respectively. These estimates were nearly identical to those obtained by Meyers and Hacklander (-2.00 and -0.61, respectively).

Chambers and Just (1981) reported a shortrun elasticity of export demand for soybeans of -0.20, based on an econometrically estimated U.S. export equation for soybeans by 3SLS that used quarterly data for 1969(I) - 1977(II). As pointed out earlier in the review of wheat elasticities, this model used U.S. population to define the dependent variable. Explanatory variables in the export equation include: the price of soybeans at Chicago, deflated by a wholesale price index; a lagged dependent variable; the U.S. dollar/SDR exchange rate; non-U.S. exports of soybeans; and three seasonal dummy variables. Using the shortrun price elasticity and the coefficient on the lagged dependent variable, the longrun price elasticity for U.S. soybean exports was calculated to be -0.29 -- the lowest longrun estimate found in the survey.

Gadson, Price, and Salathe estimated U.S. export equations for soybeans, meal, and oil in constructing the FAPSIM model. The distinguishing feature of these equations is that they include foreign exchange holdings for Japan and the EC as an explanatory variable. Other explanatory variables in the soybean equation included: the price of soybeans in Illinois, deflated by the U.S. dollar/SDR exchange rate; a livestock production index for the EC; and dummy variables for 1971 and 1974. U.S. soybean meal exports were defined as a function of the soybean meal price deflated by the exchange rate variable; the fishmeal price at European ports as the competing meal price; the EC livestock production index; Brazilian soybean meal exports; and a dummy variable for 1971. Soybean oil exports were estimated as a function of the soybean oil price, deflated by the exchange rate variable; Japan's and the EC's foreign exchange holdings; and dummy variables for 1972, 1969-70, and 1975. The authors estimated the equations using OLS for 1961 (1962 for soybeans) to 1979. Elasticities were not reported in this study but were subsequently calculated at the data means. The shortrun price elasticity was -0.19 for soybeans, -0.51 for soybean meal, and -0.24 for soybean oil, which are at the low end of the studies surveyed.

Green and Hoskin (1982) estimated an export demand equation for soybeans using OLS and covering 1955-79. They reported a shortrun elasticity of export demand for soybeans of -1.10. The elasticity was calculated at the mean for the most recent 5-year period (1975-79). All prices were deflated by an exchange rate variable. The soybean export equation was nearly the same as that in the Meyers and Hacklander study, although the exchange rate was not included as a separate regressor. A similar procedure was used to obtain an export demand elasticity of -0.55 for soybean meal.

Helmberger and Akinyosoye (1984) estimated a U.S. soybean export equation for use in a model of competitive storage under uncertain conditions and assuming

rational expectations. The equation was a function of the price of U.S. soybeans deflated by the consumer price index, soybean production in Brazil, an index of EC national income, and farm animal population in Japan. The authors obtained a shortrun price elasticity of demand of -0.14 by estimating the export equation with 3SLS for 1948/49-1977/78. The elasticity estimate is the lowest of all the studies reviewed, probably due to the exclusion of an exchange rate variable. However, the estimated price coefficient used to calculate the elasticity was not statistically significant at the 10-percent level.

#### Calculation Method

Only a few studies in this survey obtained elasticity estimates for soybeans and their products by the calculation method. Johnson (1977) estimated the longrun elasticity of export demand for U.S. soybeans at -2.8. He used a domestic demand of -0.4 and a domestic supply elasticity of 0.23 and assumed these held for all countries that imported soybeans from the United States to avoid aggregation problems across regions.

Bredahl, Meyers, and Collins (1979) used Johnson's domestic supply and demand elasticities for importing countries to compute longrun U.S. soybean export demand elasticities under various trade policy environments. Estimates ranged from a low of -0.39 (in the case when only the EC and Japan had a price transmission elasticity equal to 1) to a high of -1.12 when all regions had a transmission elasticity equal to 1 (free trade). An intermediate case (their approximation of the real world) had a computed export demand elasticity of -0.47. This estimate is only about a sixth as large as the estimate obtained by Johnson. The discrepancy is explained by the authors' adjustments for domestic and trade policies, while Johnson's estimate implicitly assumes perfect price transmission. However, their estimate appears low for a longrun estimate and is below many shortrun estimates. Their soybean elasticity was much lower than the corresponding estimates for coarse grains (-1.31) and wheat (-1.67).

Dunmore and Longmire's (1984) longrun elasticity of export demand for soybeans (meal equivalent) was -0.97, based on assumed price transmission elasticities and domestic supply and demand elasticities reported in other studies for one exporting region (Argentina-Brazil) and five importing regions. As with Bredahl, Meyers, and Collins, their export demand elasticity for soybeans was lower than that for coarse grains. Their wheat estimate (-0.89), however, was less elastic than that for soybeans. In a related study, Dunmore (1984) found that in a situation of free trade (when all the price transmission elasticities were set at 1), the soybean export demand elasticity increased to only -1.04. This increase was much lower than similar changes for coarse grains and wheat and reflected largely the nearly free-trade environment which exists for soybeans.

Gardiner's estimate of the longrun export demand elasticity for soybeans (-1.03) was calculated from elasticities of supply, demand, and price transmission for the European Community and a rest-of-the-world region. The estimate is only slightly elastic and between the other two estimates obtained by the calculation method.

## Simulation Method

Only one study in this survey contained elasticities for soybeans and their products based on the simulation method. Green and Price (1984) reported shortrun elasticities of export demand for soybeans, soybean meal, and soybean oil of -0.25, -0.39, and -0.27, respectively. Their estimates were based on a 1986 forecast simulation run of FAPSIM (described earlier). The behavioral equations upon which these estimates are based are described in the section covering direct estimation.

## Synthetic Method

Three of the studies surveyed used synthetic elasticities in their soybean models. Ray and Parvin (1978) chose a shortrun value of -0.65 for their soybean export equation, based on a survey of available elasticity estimates. Their estimate falls within the range of estimates obtained by Houck, Ryan, and Subotnik. Ray and Parvin chose -1.95 as their longrun price elasticity for U.S. soybean exports, which is near the upper end of reported estimates.

Holland and Meekhof (1979) used -1.00 as the value of their soybean price elasticity in the FEEDSIM model. It falls between Ray and Parvin's shortrun and longrun elasticities for soybean exports. In an updated version of FEEDSIM, Holland and Sharples (1982) added soybean meal and oil components to the model. They chose the same shortrun elasticity for soybeans (-1.00) and used -0.60 for soybean meal exports and -2.00 for soybean oil. Their soybean meal elasticity is a consensus of a number of studies that directly estimated the parameter. Their soybean oil elasticity is the highest reported.

## Evaluation

The shortrun estimates range between -0.14 and -2.00 for soybeans, -0.22 and -0.77 for soybean meal, and -0.24 and -2.00 for soybean oil. The average shortrun export demand for soybeans was -0.84 (-0.80 when the high and low values of the range were dropped). The corresponding averages were -0.47 (-0.47) for soybean meal, and -0.73 (-0.59) for soybean oil. Seven 6/ of the 13 shortrun estimates for soybeans were inelastic; all of the soybean meal estimates were inelastic; and three of five estimates for soybean oil were inelastic.

The longrun price elasticity of export demand for U.S. soybeans ranged from a low of -0.29 to a high of -2.80. It had an average value of -1.25, which fell to -1.11 when the high and low values of the range were eliminated. Three of the six longrun estimates for soybeans were elastic. There were no longrun elasticity estimates reported for either soybean meal or soybean oil.

The wide range of elasticity estimates reported for U.S. exports of soybeans and their products makes it difficult to determine their size. The large variance in estimates obtained using the direct estimation procedure is particularly disturbing because it dramatizes the sensitivity of elasticity

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6/ The four estimates reported by Houck, Ryan, and Subotnik are treated as one for this discussion since they are based on the same equation specification.



estimates to equation specifications. However, these studies indicate U.S. soybean meal exports are inelastic in the short run. The evidence for soybeans and soybean oil is inconclusive and is a subject for further investigation.

### Rice Elasticities

Only a few of the studies surveyed reported price elasticities of export demand for U.S. rice. Table 5 summarizes these elasticities.

#### Direct Estimation Method

Grant, Beach, and Lin (1984) obtained price elasticities for U.S. exports of rice from a simultaneous equations model. The model contains three separate export equations for U.S. rice: commercial milled rice exports, Government milled rice exports, and rough rice exports. Commercial milled rice exports were assumed to be a function of: the ratio of the U.S. export price and the Thailand export price, both in U.S. dollars per hundredweight; Government milled rice exports; U.S. rice supply; and the ratio of the U.S. dollar to Special Drawing Rights as an exchange rate variable. Grant and Leath (1979) did not include an exchange rate variable in their earlier study.

Government milled rice exports were a function of: the ratio of the U.S. export price to the U.S. Government support price less the U.S. export subsidy; U.S. rice supply; the ratio of Government expenditures on aided exports to the U.S. loan rate less the export subsidy; and a dummy variable for 1955-75 when the export subsidy was in effect.

Rough rice exports were specified to be a function of the U.S. farm price of rice relative to the SDR exchange rate variable, the lagged dependent variable, a policy trend variable after 1975, and U.S. rice production. The export equations were estimated along with other demand equations from 3SLS for 1950-82. Price elasticities were calculated for 1982. The U.S. commercial milled rice export elasticity with respect to the U.S. export price

Table 5--Price elasticities of export demand for U.S. rice

Study	Period	Method	Elasticity	
			Short run	Long run
Grant and Leath (1979)	1950-76	Estimation (3SLS)	-0.46 -2.11 <u>1/</u>	--
Grant, Beach, and Lin (1984)	1950-82	Estimation (3SLS)	-.68 -.53 <u>1/</u>	--
Liu and Roningen (1985)	1981 base	Calculation	--	-7.0

-- = Not available.

1/ Elasticity of demand for U.S. Government exports.



(-0.68) was slightly larger than the U.S. Government milled rice export elasticity (-0.53). This runs counter to the a priori expectation that Government exports are more price-responsive than commercial exports as the earlier results by Grant and Leath (1979) suggest. The U.S. farm price did not significantly affect rough rice exports.

#### Calculation Method

Liu and Roningen, using the calculation method, arrived at a longrun elasticity of export demand of -7.0, based on domestic supply and demand elasticities for 22 regions from the GOL model. This high elasticity value reflects in part the small relative share of U.S. rice exports vis-a-vis rice production and consumption in importing countries, as well as the large weights applied to the domestic supply and demand elasticities of trading countries when using the calculation method.

#### Evaluation

The number of studies is very limited--only two studies reported shortrun estimates. Commercial exports appear to be inelastic in the short run, while Government exports have recently become less elastic.

A better understanding of the market is needed. Unlike grains, the world rice trade is small relative to production and characterized by wide price fluctuations, low domestic response to world prices, and irregular participation by trading countries in the world market. Participants are often government agencies which move in and out of the market to maintain domestic price stability. Moreover, the United States exports a small volume relative to world production and is not a residual supplier as in other grains. Therefore, all these unique features of the world rice market need to be accounted for when estimating U.S. export demands. Single equations that provide net export demand estimates are unlikely to be adequate. A detailed model that accounts for the domestic production, consumption, and government behavior would be required to obtain reasonable estimates for the price elasticity of demand for U.S. exports of rice.

#### Cotton Elasticities

As with rice, only a limited number of studies were obtained that reported the elasticity of export demand for U.S. cotton (table 6).

#### Direct Estimation Method

Collins (1979) used OLS and annual data from 1958-77 to obtain two separate estimates for the shortrun elasticity of export demand for U.S. cotton exports. His first equation included the U.S. cotton price in Liverpool, England, the U.S. price index of cotton-broadwoven goods, an index of industrial production in all countries belonging to the Organization for Economic Cooperation and Development (OECD), and exportable production in competing exporting countries. Using 1976 data, he obtained an elasticity of -0.87. The second equation that Collins estimated also included the ratio of the U.S. cotton price to competing cotton price. The elasticity obtained from this equation is much larger (-3.55). In addition to shifts of a single world

demand curve, this elasticity captures the import substitution created when U.S. and foreign prices deviate. Based on these estimates, and combined with information from Bredahl, Meyers, and Collins (1979), he concluded "... shortrun elasticities between -0.4 and -1.0 and moderate run elasticities between -0.9 and -1.5 seem reasonable."

Collins (1980) reported a shortrun elasticity of export demand of -0.10, based on a total import demand equation for cotton for all major importing countries except India. However, the price variable on which the elasticity was based was not significant at the 95-percent level.

Taylor and Collins (1981) estimated export demand equations for each of the four cotton products: cotton lint, seed, oil, and meal. Estimation was done by seemingly unrelated regression (SUR). Cotton lint export demand equations were estimated in a separate block than seed, oil, and meal. Parameters were restricted to conform to symmetry and homogeneity. Taylor and Collins did not directly report elasticities, however. Using their estimated price coefficient and the 1982 price and quantity values, the shortrun elasticity for U.S. cotton exports was calculated to be -0.02.

#### Calculation Method

Johnson's (1977) longrun export demand elasticity of -5.5 for cotton was based on 1970 price and quantity data. The domestic demand elasticities used in

Table 6--Price elasticities of export demand for U.S. cotton

Study	Period	Method	Elasticity	
			Short run	Long run
Collins (1979)	1958-77	Estimation (OLS)	-0.87 <u>1/</u> -3.55 <u>2/</u>	--
Collins (1980)	1961-78	Estimation (OLS)	-.10	--
Taylor and Collins (1981)	1961-80	Estimation (SUR)	-.02	--
Johnson (1977)	1970 base	Calculation	--	-5.5
Bredahl, Meyers, and Collins (1979)	1972/73- 1975/76	Calculation	--	-.65
Liu and Roningen (1985)	1984 base	Calculation	--	-4.6
Green and Price (1984)	1986 base	Simulation	-.24	--

-- = Not available.

1/ Based on the U.S. cotton price in Liverpool, England.

2/ Based on ratio of U.S. cotton price to competing cotton price and the U.S. cotton price in Liverpool, England.

calculating the elasticity were assumed to be -0.20 for all cotton-importing countries, which was the same value used in calculating the wheat elasticity. All domestic supply elasticities were 0.20. This study implicitly assumed perfect price transmission (elasticity of price transmission was equal to 1).

Bredahl, Meyers, and Collins (1979) used the same domestic elasticities as Johnson, but three separate scenarios of price transmission elasticities to demonstrate the elasticity-reducing effects of trade and domestic policies. They obtained three longrun export elasticities that varied from -0.39 (restrictive trade) to -1.92 (free trade). An intermediate elasticity of -0.65 represented the real world situation.

Liu and Roningen (1985) arrived at a longrun export demand elasticity of -4.6, based on domestic supply and demand elasticities for 22 regions from the GOL model. Liu and Roningen's estimate is larger than Bredahl, Meyers, and Collins' "real world" estimate but slightly smaller than Johnson's estimate.

### Simulation Method

The only cotton elasticity estimate reported from a simulation exercise was obtained by Green and Price (1984) using the FAPSIM model. They reported a shortrun price elasticity of -0.24 for U.S. cotton exports. The price variable upon which this estimate is based is the U.S. mill price of cotton (in cents per bushel), deflated by an exchange rate index of importing countries. Other explanatory variables in the FAPSIM cotton export equation include: man-made fiber production outside the United States, cotton supply in importing countries, and real gross disposable income in developed countries.

### Evaluation

The shortrun price elasticity of export demand for cotton ranged from a low of -0.02 to a high of -3.55, and averaged -0.96 for the studies reviewed. The average elasticity fell to -0.40 when the high and low values of the range were excluded. Four of the five shortrun elasticity estimates were in the inelastic range.

The longrun price elasticity for U.S. cotton exports ranged from a low of -0.65 to a high of -5.5, and averaged -3.58. Dropping the high and low values of the range yields the elasticity value of -4.6. Two of the three longrun estimates reported were elastic.

Like the survey of rice studies, an insufficient number of cotton studies were found to reach any definite conclusions about the size of the price elasticity of export demand for U.S. cotton. The evidence suggests that exports are not very price responsive in the short run (1 year or less). However, one study, which reported both elastic and inelastic estimates (based on export equations which differed by a single variable), illustrates how sensitive the estimates are to equation specification.

## CONCLUSIONS

Many studies estimated elasticities of foreign demand for the major U.S. agricultural commodities. Based upon a review of 45 U.S. commodity studies, there appears to be little consensus on the magnitude of the empirical estimates. Schmitz, McCalla, Mitchell, and Carter (1981) reached a similar conclusion when evaluating three studies that attempted to estimate the elasticity of demand for U.S. agricultural products.

The elasticity parameter for each of the commodities varies immensely from very inelastic to very elastic in both the short run (less than one year) and the long run (greater than one year). Even though definitive estimates for the elasticity of export demand are not available, the shortrun elasticity of demand for U.S. exports of grains (except sorghum), soybean meal, and cotton is inelastic. For the other commodities (soybeans and soybean oil), there is less evidence to establish the degree of price-responsiveness for the short run. For the long run, the evidence is even less conclusive. There are substantially fewer studies that estimate the longrun price elasticity of demand for U.S. agricultural products. Those that are available range from very inelastic to very elastic.

The wide variation in elasticity estimates reported in the literature is attributed primarily to differences in methodology, assumptions, and period of analysis. Of the 45 studies reviewed in this report, 25 obtained estimates of export demand elasticities using the direct estimation method, 11 studies used the calculation method, 5 studies used the synthetic method, and 4 studies used the simulation method.

The direct estimation method poses a variety of problems for the researcher, including: specification errors, data inadequacies, multicollinearity, and aggregation problems. Since the elasticity of export demand summarizes in one parameter the reactions of both importers and exporters to a change in the U.S. commodity price, a properly specified export demand equation should include all shifters of domestic supply and demand schedules in all trading countries along with transportation costs, exchange rates, and trade policies. This is simply too much to ask of a single equation. There needs to be a disaggregation of the export demand equation into its individual components--the supply and demand schedules of importing and exporting countries.

A review of studies that have reported the elasticity of export demand using the calculation methodology indicates a number of limitations. In most instances, the domestic demand and supply elasticities were not estimated. In other cases, the authors used elasticities from various sources but did not report either the source or the periods from which these elasticities were estimated. There needs to be an effort in the profession to estimate these domestic elasticities, thus allowing for a more true expression for the elasticity of export demand.

Few of the studies provided empirical estimates of the price transmission elasticities. As shown by Bredahl, Meyers, and Collins, and Dunmore and Longmire, the value of the price transmission elasticity can affect the export demand elasticity immensely. A number of studies attempted to circumvent this



problem by estimating domestic elasticities with respect to world price. However, it is not possible to observe directly how changes in domestic and trade policies of other countries impact U.S. export demand elasticity.

Few studies obtained elasticity estimates that took into account transport and other transactions costs. As noted earlier, excluding these costs from direct estimates could bias the elasticities estimates. Many studies failed to account for effects of changing government policies on the export demand elasticity, which would also lead to biased estimates. Comparing the results of studies which accounted for government policy with those that did not illustrates the extreme sensitivity of elasticity estimates to assumptions about the effect of government policy. Abbott (1979) suggests a modified approach to estimating international trade flows. This method would improve results regarding price response by endogenously incorporating government trading policies.

The calculation method and the simulation method, however, represent more disaggregated approaches to estimating the elasticity of export demand and thereby permit using more economic and policy variables than in the direct estimation method. The calculation and simulation approaches should yield a more accurate estimate of the elasticity of export demand facing the United States for each of its commodities. But these approaches require large amounts of data, time, and money to estimate elasticity of domestic supply, domestic demand, and price transmission for trading countries. Furthermore, some earlier studies that used the calculation method failed to adequately account for policy interventions, exchange rates, or transportation costs, implying a price transmission of 1 which resulted in unreasonably high estimates of the elasticity of export demand. Thus, the more disaggregated approaches to estimating export demand elasticities improve on the direct estimation approach only to the extent that the additional information accurately reflects the commodity market under scrutiny.

The synthetic approach to obtaining elasticity estimates represents an educated guess based on some synthesis of actual estimates of elasticities and the researchers' knowledge of the commodity market. Thus, elasticity estimates obtained in this manner (empirical estimates tempered with expert opinion) might more accurately approximate the "true" value of the elasticity of export demand than would either approach taken separately.

We do know that the elasticity of export demand for a commodity changes over time as a result of changes in world trade, U.S. market share, domestic structure, government policy, and macroeconomic conditions. This accounts for part of the variation in the elasticity estimates found in the literature. One implication is that estimates based on data for the sixties and seventies may not be appropriate for the eighties. Thus, elasticity estimates, because of their volatile nature and their importance for policy analysis, need to be continually updated if they are to accurately reflect the response of the rest of the world to a change in U.S. commodity prices. This will entail an enormous commitment of resources to continually update data bases, account for policy changes, and estimate supply, demand, and price transmission elasticities of trading countries.

There is also a strong need to refine and expand existing data sources if more accurate elasticity estimates are to be obtained. While quantitative data exist for most trading countries for the principal commodities, much of the data are annual time series reported on either a calendar year or a crop year basis, which often differ from the U.S. crop year. In addition, U.S. commodity data are often reported on different crop years--year beginning June 1 for wheat, barley, oats and rye; August 1 for rice and cotton; September 1 for soybeans; and October 1 for corn and sorghum. Furthermore, most of the macroeconomic data used in annual commodity market models are on a calendar year basis.

Price data are plagued with the same shortcomings as the quantitative data in addition to a number of other problems. Commodity price series for some countries either do not exist or are available for only a limited time period. The price series which do exist on either an annual or quarterly basis are usually simple averages of price data collected over a shorter time (such as monthly) rather than weighted averages in which the quantity of sales are used as weights. This results in price series which do not accurately reflect the level of market activity which occurred at that price level. Furthermore, national average price series do not exist for certain commodities so that the price in a certain city, port, or region is used as a proxy.

Once an elasticity estimate has been obtained, the problem of interpreting it arises. By definition, the price elasticity of export demand indicates the percentage change in the quantity of exports demanded for a given percentage change in price, all other things held constant. That is, the price elasticity defined in this manner measures only the direct effect of a price change and does not account for cross-price effects or the indirect effects that the price change has on other economic variables such as income, foreign exchange holdings, and the consumer price index. Thus, a price elasticity will likely underestimate the net effect of a price change on exports as a result of the feedback effects of price on other economic variables.

Elasticities based on the simulation method, however, do not hold all things constant, and therefore, resemble dynamic multipliers rather than elasticities in the pure sense. Estimates based on the simulation method are more likely to yield a better assessment of the effect of a price change than estimates that measure only the direct price effects.

Furthermore, elasticities hold only for small movements around the point at which they are calculated, implying that the effect of a price change on export demand as implied by the elasticity may not be valid for large price changes. A large price decline might result in less price response (less elastic) than the elasticity implies, while a large price increase might yield an even stronger price response (more elastic).

There is also some uncertainty about the symmetry of the price response implied by an elasticity; that is, is the response to a price rise the same (but opposite in direction) as the response to a price decline? This is particularly true of elasticities that have been estimated over periods of rising prices. In this case, the elasticity might be valid for evaluating the effects of a price rise but would it be appropriate for evaluating the effects



of a price decline? Certain institutional rigidities such as government price support programs or self-sufficiency goals might prevent competing suppliers from immediately reducing their production in the face of a price decline. In this case, a price decline might require a longer adjustment period than a comparable price rise. On the other hand, Schuh (1976) states, "to the extent asymmetry exists in supply response, the rigidity may now be on the up side rather than on the down side."

The length of time (or run) for measuring the effects of a price change is cause for much confusion in measuring and interpreting elasticities. The short run is generally defined as 1 year or less for annual crops such as grains and oilseeds because production of annual crops is assumed to occur only once a year. While this might be valid for an individual country, in a global context, production of a particular crop occurs throughout the year. Thus, there is actually more supply response in the short run as defined here than is generally assumed. Some studies only consider consumption and stock changes for the year in estimating export demand elasticities for the short run and treat supply response as a longrun phenomenon.

The definition for the long run is even more nebulous. It is generally defined as a period beyond 1 year. Since most elasticity estimates are based on annual data, the longrun elasticity generally implies the response in the second year after a price change. However, many studies using the calculation method or the simulation method assume a different period of adjustment for the long run -- 3, 4, or 5 years. Some of these time periods might even be described as "intermediate run". Thus, definitions of the time period of adjustment (or length of run) need to be standardized or at least made more explicit.

While the price elasticity of export demand can be a useful parameter for evaluating the effects of a price changes, extreme care must be exercised not only in estimating this elusive parameter but also in interpreting it.

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